

# C/O Abundance Ratios and Dust Features in Galactic Planetary Nebulae

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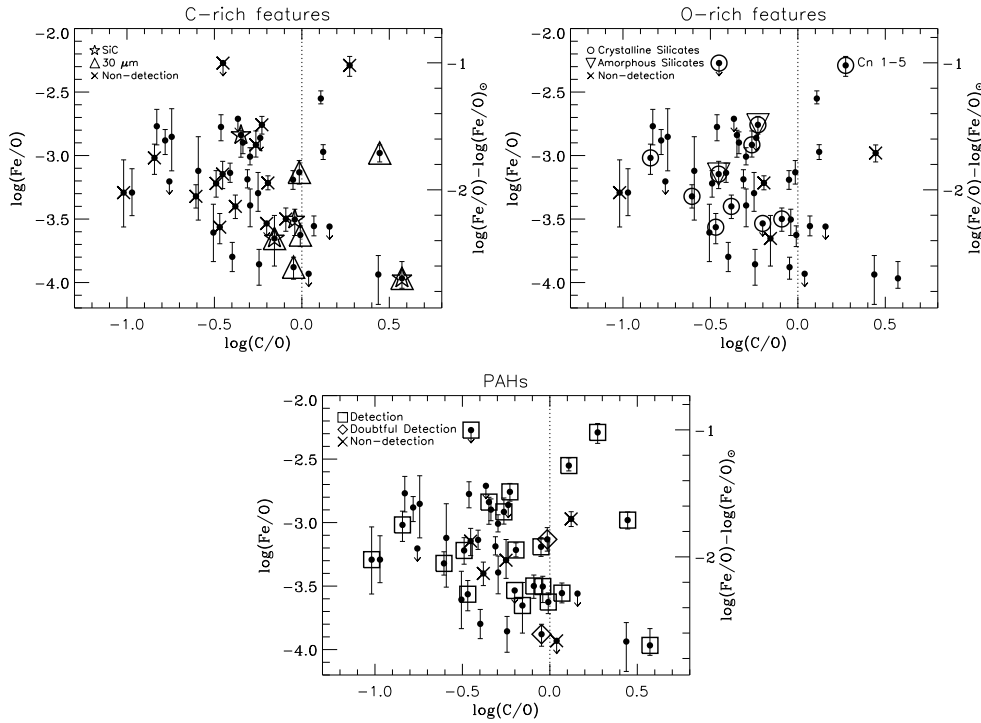
**Abstract.** The iron depletion factors found in Galactic planetary nebulae (PNe) span over two orders of magnitude, suggesting that there are differences in the grain formation and destruction processes from object to object. We explore here the relation between the iron depletions, the infrared dust features, and the C/O abundance ratios in a sample of Galactic PNe. We find that those objects with  $C/O < 1$  show a trend of increasing depletions for higher values of C/O, whereas PNe with  $C/O > 1$  break the trend and cover all the range of depletions. Most of the PNe with  $C/O < 1$  show silicate features, but several PNe with C-rich features have  $C/O < 1$ , probably reflecting the uncertainties associated with the derivation of C/O. PAHs are distributed over the entire range of iron depletions and C/O values.

**Keywords.** Planetary Nebulae: general, ISM: abundances, dust, extinction, infrared: ISM

We have constrained the gaseous iron abundances in a sample of Galactic planetary nebulae (PNe) with good quality optical spectra, using [Fe III] lines and the correction scheme of Rodríguez & Rubin (2005). From these abundances we can estimate the depletion factors for Fe/O using  $(Fe/O)_{\odot}$  as a reference value for the total Fe/O abundance (in gas and dust):  $[Fe/O] = \log(Fe/O) - \log(Fe/O)_{\odot}$  (see Delgado-Inglada et al. 2009; Delgado-Inglada & Rodríguez, 2011 in preparation). The range of iron depletions covers two orders of magnitude, suggesting differences in the grain formation and destruction processes from object to object. These differences could be related to the chemistry of the environment. The value of C/O in the atmospheres of asymptotic giant branch stars, the progenitors of PNe, determines whether C-rich or O-rich grains are formed. Therefore, the C/O abundance in the ionized gas of PNe is likely to be related to the different dust features observed in their infrared spectra. We study here the relation between the iron depletions, the infrared features, and the C/O ratios derived in a sample of Galactic PNe.

Figure 1 shows the values of Fe/O and [Fe/O] as a function of the C/O abundance ratios. The values of  $C/O \simeq C^{++}/O^{++}$  were derived using recombination lines for 48 PNe with available measurements. The use of these lines avoids the problems related to the combination of optical and ultraviolet observations, required when using collisionally excited lines. However, the C/O values are generally very uncertain, with discrepancies between the different methods (that use either recombination or collisionally excited lines, and different corrections for unobserved ions) of up to 0.6 dex. Figure 1 also shows the different dust features found in 32 objects. We have reduced the available Spitzer/IRS spectra for our sample PNe, and compiled other identifications from the literature (Delgado-Inglada & Rodríguez, 2011 in preparation). The infrared features we use are the ones that are easily identified in the spectra and that can be reliably associated with a C-rich or O-rich environment: PAHs, SiC, the wide feature at  $30 \mu m$  usually attributed to MgS (Hony et al. 2002), amorphous silicates and crystalline silicates.

PNe showing the broad feature at  $30 \mu m$  and/or the SiC band are expected to have  $C/O > 1$ , but this is not the case for some of our objects, suggesting that their C/O



**Figure 1.** Values of Fe/O (left axis) and the depletion factors [Fe/O] (right axis) as a function of C/O. We identify the dust features found in the sample PNe.

values are wrong. On the other hand, most, maybe all, of the PNe with  $C/O < 1$  show silicate features. We cannot rule out the presence of these features in two PNe shown as non-detections in Figure 1 due to the poor quality of their spectra. The other non-detection, M1-20, shows carbonaceous dust features and is likely to have  $C/O > 1$ . On the other hand, Cn1-5 is the only PN with  $C/O > 1$  that shows silicates. Either the  $C/O$  ratio is wrong for this nebula, or the silicates formed in a previous O-rich evolutionary stage of a now C-rich nebula. In such case, the silicates could be stored in a long-lived disk (Waters et al. 1998). We find that PAHs are present in all the PNe with good quality infrared spectra (the halo PN DdDm 1 could be an exception). PAHs are distributed in the whole range of iron depletions and  $C/O$  values. The presence of PAHs is expected in C-rich environments; in O-rich PNe, PAH emission could arise in the surrounding interstellar medium or in a dense O-rich torus, where PAHs could form, as proposed by Guzmán-Ramírez et al. (2011). The iron depletions increase with  $C/O$  for those objects with  $C/O < 1$ , whereas objects with  $C/O > 1$  cover the full range of iron depletions. This could be due to gradual changes in the dust composition when  $C/O$  increases, up to  $C/O = 1$ , when there is an abrupt transition in dust composition.

## References

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